`

MACHINE LEARNING APPROACH ON RISK ASSESSMENT FOR EXPLOSION AVOIDANCE IN FIREWORK INDUSTRIES

A SYNOPSIS

Submitted by

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1. INTRODUCTION

Pyrotechnics, which are more commonly referred to as fireworks, were first developed in China in the 14th century. India started manufacturing fireworks in the nineteenth century. Sivakasi a town in Virudhunagar district in the state of Tamil Nadu is a hub for production of firework products. Ninety percentage of the firework products were manufactured and exported to several countries. From the primary stage of manufacturing till the transportation and storage of the firework products are of high risk [1]. However, the production process in these industries is entirely manual. The dry and hot climatic condition throughout the year is the main reason for the large production in this area. As with any other industrial industry, the fireworks industry is exposed to hazards and risks. Hazard is a factor that can cause harm, whereas risk is the possibility that something will occur [2]. This research focuses on hazard identification and risk assessment in order to improve safety standards or procedures in the fireworks business [3]. Figure 1 depicts a variety of prominent dangers in the fireworks industry, including fire, hazardous discharge, explosion, and others.

Figure 1. Hazards in the firework industry

There are always several factors at play that can lead to an adverse event, and this makes taking chances more likely. Therefore, dangers must be promptly controlled to ensure safety. From the first stages of production planning through the last stages of

product distribution, risks change from one location to the next and from one process to the next [4]. In order to successfully manage risks, thorough hazard identification and risk assessments must be conducted. Accident histories are analyzed to determine potential dangers. The fireworks business is not one that relies much on statistics. Therefore, the majority of information is collected from past accident records and survey results. Once information has been gathered, it can provide a depth of understanding [5]. The district of Virudhunagar is the focus of this study's research efforts. Surveys were used to gather information from roughly 75 different fireworks companies.

The identification of accident contributing elements is a necessary effort in order to assure safety in the fireworks industry. The survey detects potential risks as well as important air conditions that could lead to mishaps. Hazard Identification and Risk Assessment (HIRA) is a risk assessment process that detects hazards and evaluates the risks associated with them. HIRA is a four-step process that includes hazard identification, risk assessment, risk analysis, monitoring, and review.

The "Risk assessment" is the process of detecting and assessing potential events that may harm people, property, or the environment, while taking influencing variables into account. Risk evaluations are vital for the fireworks sector and all others. The industry needs them to run smoothly. In hazard detection and risk management, analytics can help make decisions and get insights [6].

The use of cutting-edge techniques such as machine learning and neural networks would make it easier to identify insights in data and assist us in visualizing and grasping the industry's vulnerabilities and threats. A recommendation system is a type of information filtering system that employs machine learning algorithms to suggest or anticipate a desired item, value, or feature based on current data. [7]. In the pyrotechnics industry, recommendation systems can be used to determine hazards and what will happen if manifest [8].

2. LITERATURE REVIEW

India is a developing country, and it is the world's second largest manufacturer of firecrackers. The manufacture of fireworks requires a large number of manpower and is prone to occupational accidents. An occupational accident is an unexpected and

unplanned occurrence. Occupational accidents are widespread in the fireworks industry due to a lack of safety precautions and training. Workplace accidents can be caused by both hazardous conditions and unsafe actions.

Ashifa examined the safety measures implemented by Tamilnadu's firework industries and identified the current safety measures in use in this industry. because in industries, safety and health are of the utmost importance The factory act mandates that safety equipment be prioritized [2]. The author examined the safety measures in this industry, which they believe should be prioritized. The study also says that officials from both the state and federal governments should help install safety systems in factories that make fireworks in Sivakasi [3]. This would help prevent accidents in the fireworks industry.

Prabhavathi et al., proposed an approach to understand and anticipate industrial disasters [8]. The industrial data is acquired from one of the world's largest corporations, which tracks industrial accidents in every country. To understand the reasons for such catastrophes and how to forecast future accidents, the data is researched and produced using a machine learning algorithm. They were reasonably accurate in predicting future accidents.

To improve industrial safety, risk assessments must be performed effectively. Hazard and risk identification is an important tool to analyze the risk factors in industries [9]. Sunaryo and Hamka M.A. proposed a system for safety risk assessments based on the activity sequences. The Hazard Identification and Risk Assessment (HIRA) method is used to identify the kind, cause, and effect of potential dangers. The risk level is calculated using a risk matrix. With the assessment data, rules or suggestions can be made to make the fireworks industry safer [10].

Rajaram and Sivakumar identify the safety culture in the fireworks industry based on factors such as work environment, worker awareness, process, governance, and safety satisfaction [11]. Statistical tools such as SPSS and AMOS are used to run various statistical tests, such as reliability and validity. This field study looks into how workers in the fireworks industry feel about safety. The goal is to find out what really happens and give suggestions to management on how to prevent accidents, fires, and explosions to save workers' lives [16].

Wang et al., analyzed the raw materials that are hazardous to handle, such as aluminum and sulfur, which are susceptible to pressure, temperature, frictional heating, and humidity [12]. Delen et al., created artificial neural networks (ANNs) as computational approaches for analyzing workplace events, forecasting injury causes and severity, and identifying influencing factors. The review is generic and geared toward common workplace accidents [13].

The use of machine learning and deep learning techniques has been quite popular in analysis over the last decade [13]. Recent research has utilized modern machine learning and deep learning approaches for various analyses in the firework industry. Because the number of hazards in the industry is greater, accident prevention is an important mission for the firework industries to achieve. Several aspects contribute to accidents, such as human factors (HF), atmospheric conditions, chemical hazards, worker knowledge level, logistical shortcomings, and more [14, 17]. Thus, the use of modern techniques will highlight several insights and result in better security and safety.

In this research, several futuristic analyses are made based on key aspects such as the risk assessment, influencing human factors, and atmospheric conditions, especially the impact of Zeolite on them. From the analysis, suggestions or recommendations are made to cut down on accidents and make the environment safer.

3. OBJECTIVES

1. To identify the consequence factors of hazard and risks in Firework industries.
2. To predict influencing atmospheric conditions using machine learning for explosion avoidance.
3. To analyse and classify the quantity of zeolite impact to maintain atmospheric condition in chemical processing and storage.
4. To apply machine learning algorithms to classify human factors in manufacturing units for hazard free environment.

4. RESEARCH PROBLEMS

4.1. Data Collection

Data collection is the first work done in this research study. The primary data is collected from a questionnaire survey of workers, owners, supervisors, foremen, and locals in this area. Secondary data includes accident reports from the previous year, website information, and information from nearby police stations, fire stations, and government hospitals. The major accident-causing factors are analyzed and listed as part of the risk assessments. This study made use of a descriptive method for data collection, with a survey containing four demographic factors: gender, age, experience, and position. A checklist, yes/no questions, a Likert scale, and a rating system were all part of the survey. The checklist is intended to identify the hazards in the factory. The questionnaire focuses on various critical factors, including managerial activities, the work environment, employee information, and the process.

4.2. Identifying Hazards and Risks Using HIRA

The possible risks are identified, it involves four key process Risk Assessment, Risk Analysis, Monitoring, and review. F test method was conducted to determine whether the means of the principal risk factors were significantly different. F-Test divides two variances, s1 and s2, and compares them using an F Statistic. Also, the HIRA method is used to evaluate which sub-factors significantly affect the safety perception of workers to identify the risk zone. The risk scores were determined based on the severity and likelihood.

The possibility of the hazards that can be able to occur in the industry is known as the likelihood ratings. The levels of the ratings may vary as per the industries but in most of the cases a five-scale rating is preferred (1-very rare, 2-rare, 3-unlikely, 4-possible and 5-likely). These ratings are industry specific which is based on the existing safety measures and the safety management.

The consequence of the hazards is known as severity. The effect of these consequence are categorized into different levels to know its impact on the safety of the workers. Severity ratings are obtained from the senior safety engineer in the industry as

follows; 1-negligible, 2-minor, 3-serious, 4-fatal and 5-caterospic. Risk zone calculated based on the risk matrix depicted in table 1.

Table 1: Risk Matix

Risk Matrix			Likelihood				
			1	2	3	4	5
			Very Rare	Rare	Unlikely	Possible	Likely
Severity	1	Negligible	1	2	3	4	5
	2	Minor	2	4	6	8	10
	3	Serious	3	6	9	12	15
	4	Fatal	4	8	12	16	20
	5	Catastrophic	5	10	15	20	25

The risk zones are classified based on different stages of manufacturing process starting from manufacturing to loading/unloading. The processes involved are as follows; Chemical mixing (P1), Chemical filling (P2), Cutting (P3), Drying mixture (P4), Pallet making (P5), Fuse making (P6), Sieving (P7), Manual handling (P8), Grinding (P9), Packing/labelling (P10), Waste disposable (P11), Storage of chemical (P12), weighing (P13), and Loading/unloading (P14). Processes P1 to P14 are the factors that affect the risks. The risk zones are classified according to the Severity and likelihood conditions as

- Low (Green): Accept the risk factor
- Medium (Yellow): Reduce and control the risk.
- High (red): Significant risk factor or mitigation

The numerical values assigned to each failure mode quantify the likelihood of occurrence, detection probability, and severe effects as calculated below:

Risk Priority Number = Occurrence x Severity x Detection

The RPN reduction is calculated as

% RPN Reduction = ((RPN (Present) - RPN (Proposed)) / RPN (Present)

Risk management strategies were created based on the results derived from the HIRA process, and the analysis throws light on some insights like each work activity has a

risk factor associated with respect to manual handling of chemicals, temperature, and work environment.

4.2. Predict influencing atmospheric conditions using machine learning for explosion avoidance.

The proposed work is a neural network approach that will predict the atmospheric conditions that would influence an explosion. The proposed system utilizes an artificial neural network (ANN) with feed-forward back propagation network (FFBPN) and Levenberg-Marquardt function deployed in the 5^{th} and 10^{th} hidden layers for performance comparison among the two layers. An explosion happened during chemical mixing, drying, and pellet production is due to atmospheric conditions of temperature, pressure, and humidity. Based on atmospheric conditions, the proposed ANN model forecasts accidents and their session (afternoon or forenoon). The proposed system is analysed with historical accident data with respect to the atmospheric conditions of Sivakasi (2009-2021). Our neural network Architecture consists of a sequential stack of ten layers with two layers 5^{th} and 10^{th} utilizes FFBPN.

The Levenberg-Marquardt Back-propagation algorithm is used to train the network. The first phase involves gathering accident data from the fireworks industry based on the atmospheric conditions. The higher the effect on the manufacturing process, the more the input parameters are found. For training a model that performs two-way iterations, the FFBPN technique is used. It involves computing input weights in a forward step, and modifying weights and measuring errors in a backward step. The following parameter accident has compressed from dataset's humidity, temperature, pressure, and session data. The occurrence or non-occurrence of accidents is represented by 0 and 1, respectively mentioned in equation 1. The accident session is chemical mixing time based on Factories Act. We denote accident 0 as FN and 1 as AN, respectively. The training data is normalized to a value between 0 and 1. The dataset is split it into 70 percentage and 30 percentage for testing, training and validation.

$$x_n = \frac{x - x_{min}}{x_{max} - x_{min}} \qquad (1)$$

The maximum and minimum values of the considered variable are *x*max and *x*min, respectively, and are the normalized value of the variable x. Equation (2) trains the model until the requirements are met.

$$x_k = \sum_i^n w_{ki}\, x_i \qquad (2)$$

Since the proposed ANN is a regression model, we use the Mean Squared Error (MSE) as our loss function. Our model has 10 epochs. In a neural network, one epoch is equal to an instance of a forward/backward pass of all the training examples. A batch size is equal to the numerical value of the training examples in an instance of a forward/backward pass. Each time a batch of training examples is run, say that "iterated" through the system. Predict the best validation performance of epoch 5 on 11 epochs of hidden layer 5 and validation performance at epoch 3 on 9 epochs of hidden layer 10.

4.3. Classification of zeolite impact on Atmospheric Conditions in Processing and Storage of chemicals to avoid accidents in fireworks industry.

Chemical compounds utilized in the fireworks industry have to be stored in a stable environment where temperature and humidity have to be maintained. Zeolite is a chemical that is used to maintain the industry standard temperature and humidity in fireworks storage. When the environment is dry, it lowers the temperature (increases humidity), and when it is wet, it absorbs moisture (decreases humidity). In the proposed work, Zeolite is tested in both wet and dry states. The impact of zeolite is classified in the work for dry and wet states based on the amount it is used (5 kg, 10 kg, and 15 kg).

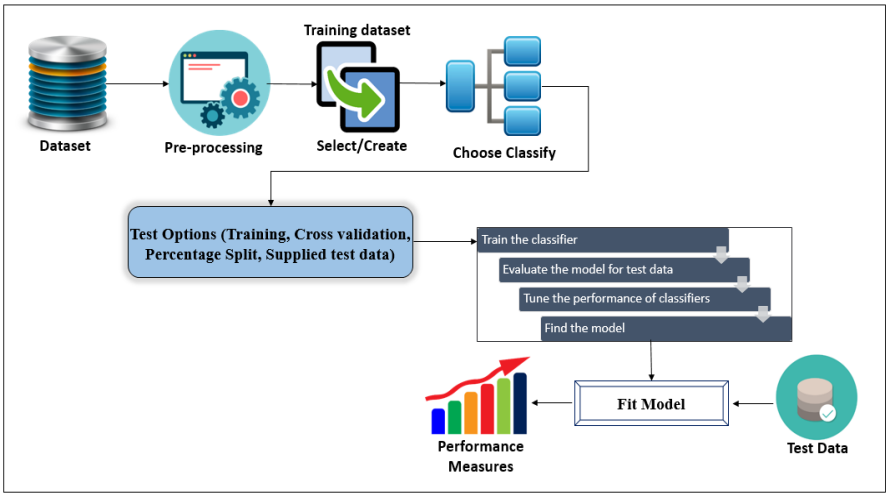

Figure 2. The Proposed zeolite classification.

Benchmark or state-of-the-art analysis and learnig models like logistic regression, support vector machines, random forests, K-Nearest, J48, artificial neural networks, Bayes' nets, and multiclass classifiers are utilized in this work. The proposed work utilizes an open-source Java-based tool named WEKA for deploying the benchmark models. The overview of the proposed work is depicted in Figure 2.

4.4. To apply machine learning algorithms to classify human factors in manufacturing units for hazard free environment.

This study utilizes the Cross Industry Standard Process-Data Mining (CRISPM-DM) approach for the deployment of ML models. It has six progressive processes, such as business intelligence and understanding, data understanding, data preparation, modeling, evaluation, and deployment. Organizational, human factors, and psychological aspects are the key data to be analyzed.

Although business intelligence is valuable, knowledge management provides two additional features. The objective of a risk evaluation is to determine what could go wrong and what risks might result from that going wrong. An analysis of the consequences of a disruption to mission-critical operations called a business impact analysis (BIA), is focused on in this model to identify the human factors.

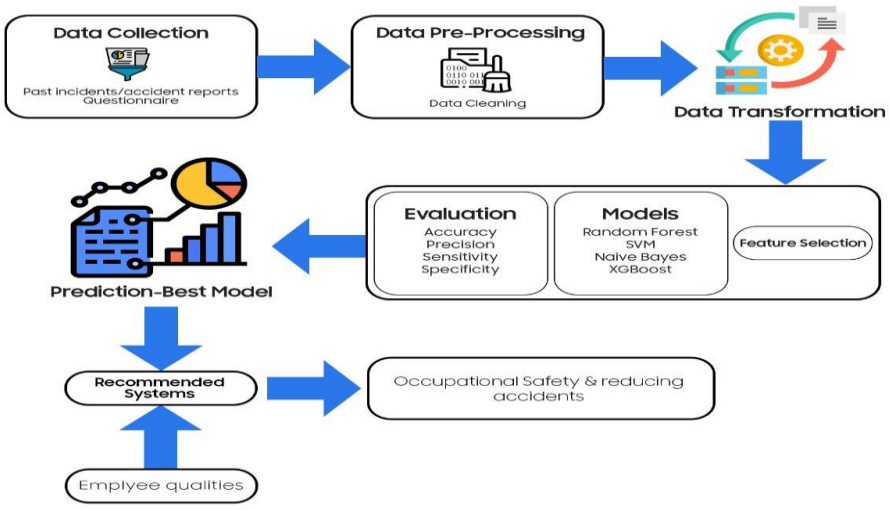

Figure 3. The Proposed system.

Four models are utilized in the proposed system, namely the Random Forest (RF), Support Vector Machine (SVM), Nave Bayes (NB), and XGBoost. The models

are evaluated using accuracy, precision, the F measure, sensitivity, and specificity metrics. The proposed system is depicted in Figure 3. As the recommendation system is based on rule-based classification, it is possible to predict the best model.

5. RESULT ANALYSIS

5.1 Identifying Hazards and Risk in Firework Industries:

Data collection is done by conducting a survey; the survey was conducted with 82 samples. The details of the respondents in terms of sex, age, experience, and position are given here. It shows that 26.83% of the workers are female, while 73.17% are male. 32.92% of the respondents are 18 to 25 years old, while 15% are 26 to 35. The majority of the respondents are aged between 36 and 50 years old. Surprisingly, 8.53 percent of workers are over the age of 50. This indicates that the firecracker industry has employed a large number of elderly employees. 25.60% of the survey respondents have more than ten years of work experience in making firecrackers, 40.24% have five to ten years, 21.95% have one to five years, and 12.9% have less than a year. Several tasks were done with the data, like risk factor identification, likelihood and severity analysis, and the development of a risk matrix. Then, with the risk matrix, risk zones were identified and classified as low, medium, and high.

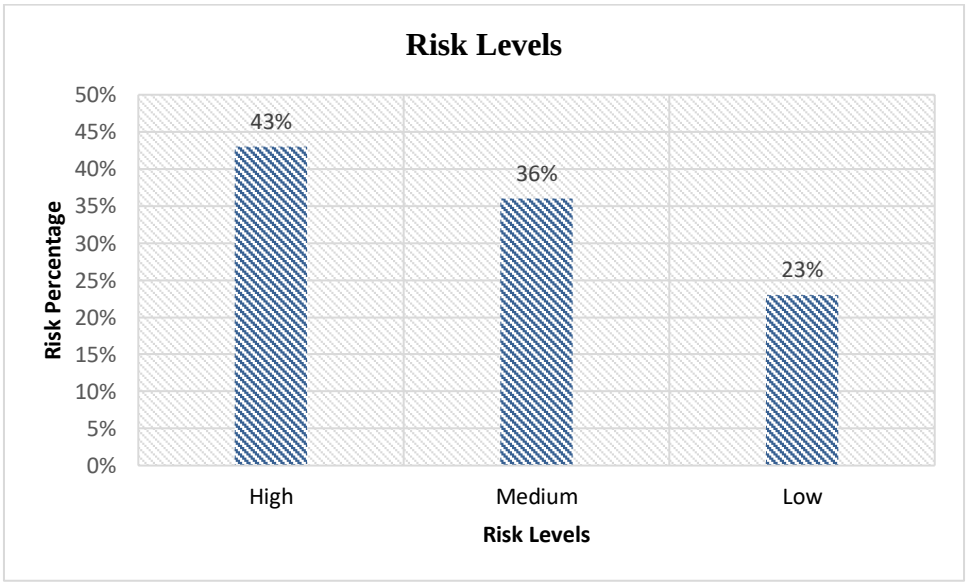

Figure 4. Levels of Risk Zones

Table 2. Risk Reduction using FMEA analysis

Factor	Failure mode	RPN Present				Existing control measures	RPN Proposed				%RPN Reduction
		O	S	D	Risk		O	S	D	Risk	
Mixing	Direct contact of harmful chemical, inhalation, wrong composition of chemicals	5	10	10	500	Specific time to be follow prescribed by factories act. Use hand gloves during material handing. All mandatory PPE's shall be use at site.. Concentrate on atmospheric conditions.	3	7	4	84	83.2%
Filling	Exceed the limit, manual handling	4	8	10	320	Avoid manual handling. Training need to be improve.	4	3	4	48	85%
Cutting	Type of tools, wrong cut, friction, heavy force	3	6	7	126	Concentrate on tools. Wooden handle and tray should be follow.	2	1	5	10	92.06%
Drying	Heat expose, lack of PPE, Floor mat	5	10	8	400	Avoid over heat. Use proper platform.	4	5	3	60	85%
Pallet making	Wrong combination, mixing density, drying platform, PPE	5	10	10	500	Chemical composition should be follow properly.	4	3	7	84	83.2%
Dipping/Fuse making	Excess chemical dip, Lack of PPE, injury	5	6	10	300	Manufacture require quantity of as per day. Based on fuse size dipping chemical	3	4	4	48	84%
Sieving	Type of tools, vessels, direct contact	3	6	5	90	Concentrate on tools. Clean the dust particle properly.	5	2	1	10	88.8%
Grinding	Spilling of chemical, ignition, inhalation	4	10	5	200	Avoid dust accumulation. Clean the excess spillages	2	10	6	120	4%
Packing / labelling	Ergonomic posture, overload	1	8	10	80	Mat and gloves need to handling. Quantity to be given as per capacity	1	2	5	10	87.5%
Waste disposable	Carelessness, mishandling of methods	4	8	10	320	Disposable methods need to be follow properly.	4	4	3	48	85%
Storage	Excess of stock	1	6	10	60	Don't allow the person to lift more than 10 kg for materials shifting from one place to other.	1	2	2	4	93.3%
Loading	Sudden ignition	5	10	5	250	Provide Trolley for materials shifting. Person handing the material should be physically fit to do work.	3	4	2	24	90.4%
Weighing	Direct contact of chemicals, vessels	3	6	10	180	Avoid direct handling of chemicals, use PPE, chemicals are weighing as per the day requirement.	1	5	2	10	94.4%
										Average % RPN Reduction	84.0%

Consequences are identified the risk zone are classified likewise P1, P2, P4, P5, P8, P11 under the high- risk zone, P3, P6, P9, P12, P14 classified as medium risk zone, and P7, P10, P13 as low-risk zone. Figure 4 illustrates that the risk zone levels based

on the hazard evaluation yielded a value of 43 percent in the high hazard category, 36 percent in the medium hazard categories, and 21 percent in the lower hazard category.

Failure mode and effect analysis (FMEA) is done based on the actual severity of the failure mode since workers cannot determine the impact of each risk. The RPN (Risk Priority Number) were calculated after the recommended actions were provided to assess the percent RPN reduction. Finally achieved 84% of risk reduction using this analysis represented in table 2.

5.2. Prediction of Influencing Atmospheric Conditions for Explosion Avoidance using Neural Network Approach.

MATLAB is used to simulate the experiment. Two ANN-based models for accident prediction in the fireworks industry have been established for this work. The mean square error (MSE) for training, testing, and validation is depicted in the respective curves. Figure 9 shows the gradient, mutation, and validation test graphs for both hidden layers in feed-forward back propagation. The hidden layer 5 predicts the gradient value to be 0.051817, the mutation value to be 0.0001, and the validation checks to be 6 at the epoch of 11. The hidden layer 10 predicts the gradient value to be 0.053452, the mutation value to be 0.001, and the validation checks to be 6 at the epoch of 9.

The Feedforward Backpropagation (FFBP) training phase performance graph is shown at epoch 5 in the hidden layer 5, which achieves the best validation performance of 0.88509, and the value of the best validation performance of 0.48294 has performed at epoch 3 in the hidden layer 10.the error histogram between the actual value and the ANN-predicted value In the hidden layer 5, as can be seen, the complete value attained is between -0.04904 and 0.202, and the hidden layer 10 value is between -0.06491 and 0.172. As the value of the absolute error increases, it moves away from the point. At the 20 iteration bins for both hidden layers. Figures 5, 6, and 7 represent the comparison of the proposed system with the other machine learning algorithms based on performance metrics.

Both the hidden layers predict the duration of accidents that occur most frequently in the forenoon of the day. Based on accuracy, the performance of hidden layer 5 outperforms that of hidden layer 10.

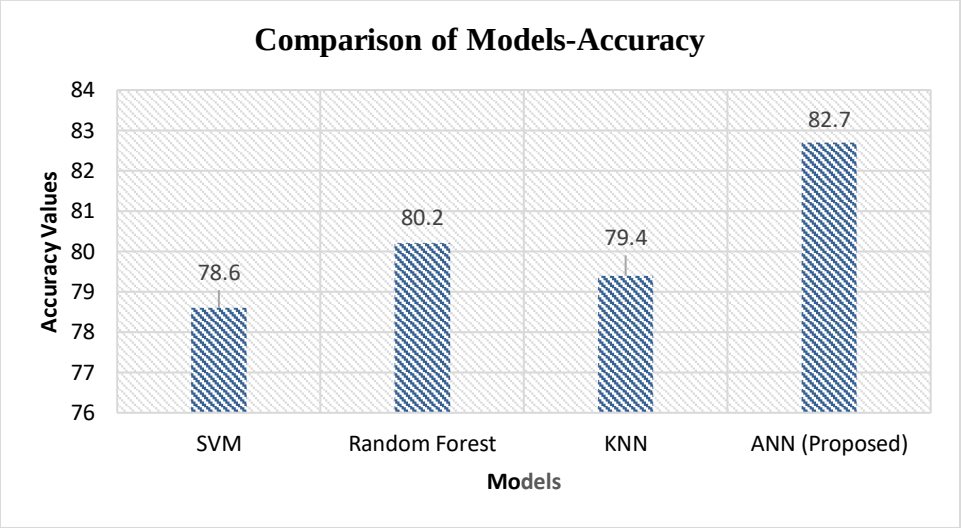

Figure 5. Models -Accuracy Values

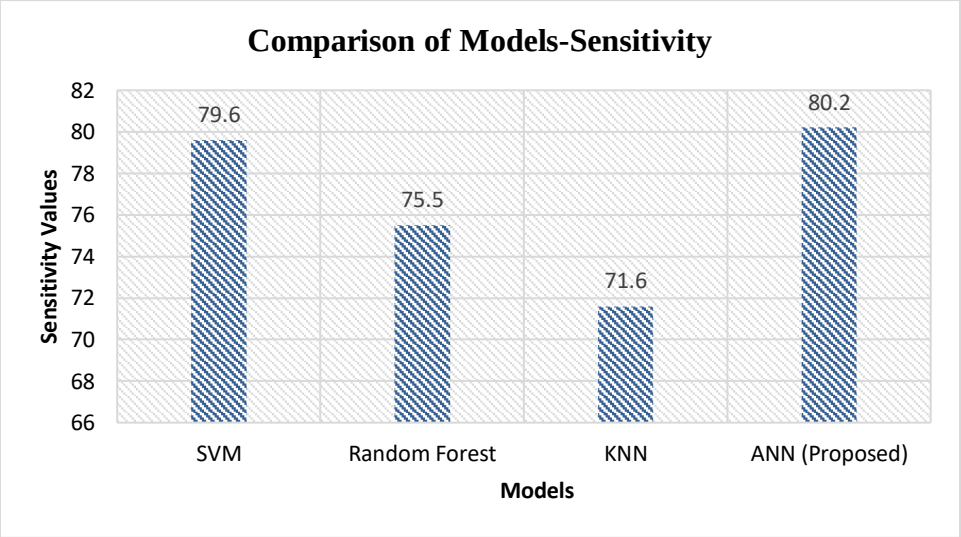

Figure 6. Models -Sensitivity Values

5.3. Classify the impact of zeolite on Atmospheric Conditions in Processing and Storage of chemicals to avoid accidents in fireworks industry.

The WEKA data mining tool was used to analyze the Nave Bayes classifier, the support vector machine (SMO), BayesNet, logistic regression, k-nearest neighbor, J48, and artificial neural networks (ANNs) in this proposed work to classify the impact of zeolite on the humidity and temperature as shown in Figure 8.

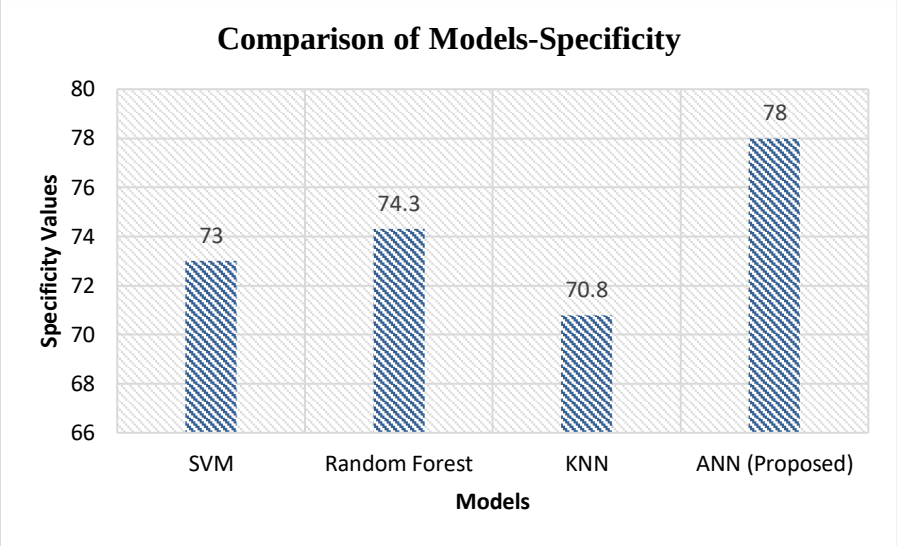

Figure 7. Models -Specificity Values

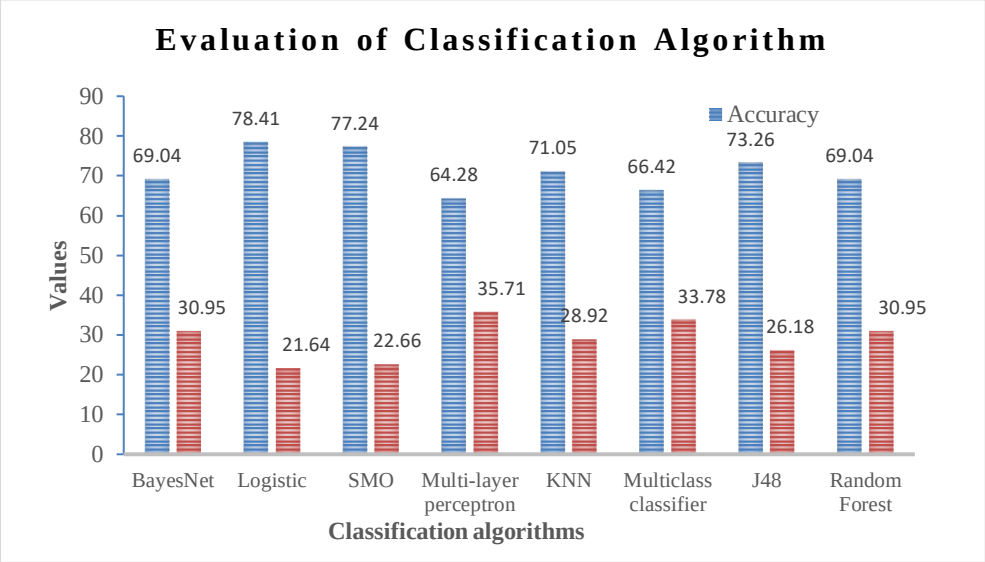

Figure 8. Evaluation of Accuracy comparison

The statistical results of the algorithms for the zeolite_safety data set are shown in Table 3 below. The accuracy, kappa statistics, mean absolute error, percent correct value, and F-measure are used in this analysis.

5.4. Application of Machine Learning Techniques for Environmental Sustainability Related on Human Influencing Factors.

This study investigates the impact of the human factor on human error. The main attributes were selected and implemented through the machine learning models. In comparison to traditional k-fold cross-validation, stratified k-fold cross-validation is

used, it utilizes the probability sampling method instead of a random one. Four benchmark models were compared. Figure 9 depicts the results where Models XGBoost and RF performed better in stratified K-10, achieving 92.75% and 91.53%, respectively, whereas Models SVM and GNB achieved 90.3% and 91.2%, respectively.

Table 3. Evaluation of Various Classifiers on zeolite_safety Dataset

Evaluations	**Bayes Net**	**Logistic Regression**	**SMO**	**Multi-layer perceptron**	**KNN**	**Multiclass classifier**	**J48**	**Random Forest**
Built time	0sec	0.5sec	.20sec	8.19sec	0sec	0.08sec	.12sec	0.14sec
Accuracy	69.04	78.41	77.24	64.28	71.05	66.42	73.26	69.04
Classified incorrectly	30.95	21.64	22.66	35.71	28.92	33.78	26.18	30.95
Kappa Statistics	0.097	0.483	0.468	0.0896	0.3304	0.1083	0.4164	0.421
Mean absolute error	0.2542	0.3016	0.2216	0.2248	0.2693	0.2496	0.3736	0.365
F Measure	0.705	0.8230	0.8231	0.8150	0.8172	0.7706	0.7801	0.8103
ROC	0.779	0.786	0.812	0.702	0.723	0.781	0.771	0.765
Class	C2	C0	C0	C1	C0	C1	C0	C2

Accuracy is used to measure the performance of these four model classifiers. An accurate description of each model may be found in Table 4. XGBoost has the best classification accuracy of 94.41% out of all the currently available models. Accuracy is 84.65% when using the GNB method. The SVM algorithm has an accuracy of 91.6%. An accuracy rate of 92.1% was achieved using RFC. Figure 10 represents the overall model performance.

Table 4: Performance metrics of all models

Models	**Accuracy**	**Precision**	**Sensitvity**	**Specificity**	**F-Measure**
GNB	86.45	90.5	79.8	74.5	84.5
SVM	91.6	86.1	96.2	60.0	87.1
RF	92.1	87.1	96.7	70.0	86.1
XGBoost Classifier	94.41	94.0	98.8	72.5	94.1

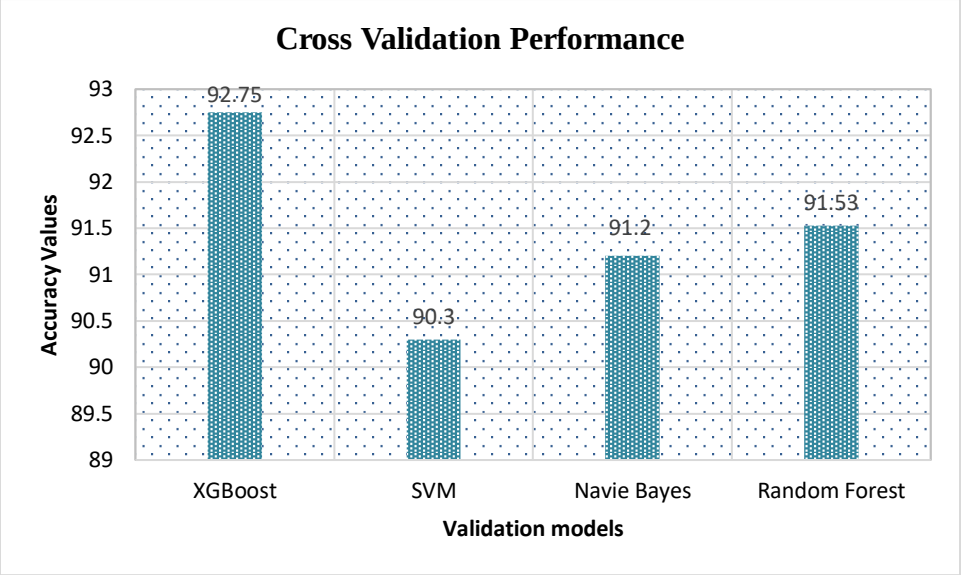

Figure 9. Stratified k Cross Validation

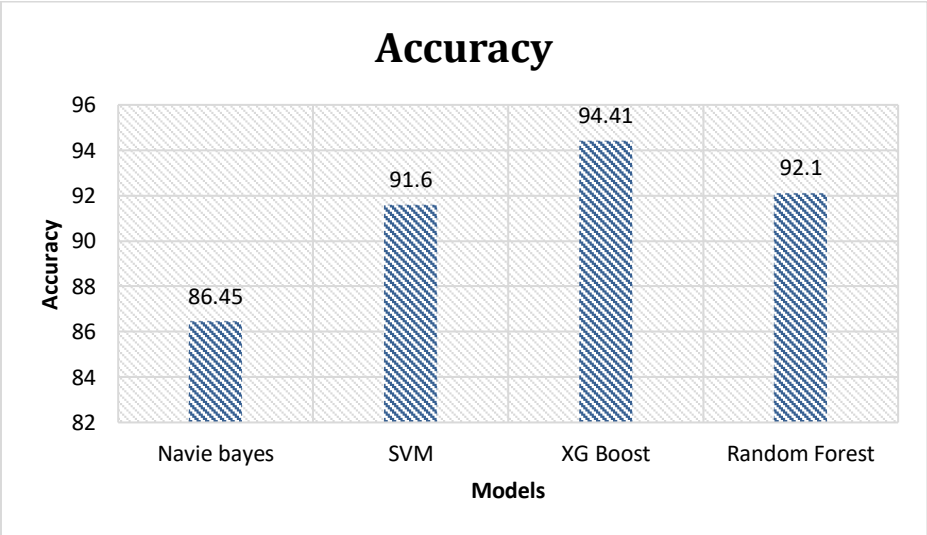

Figure 10: Overall Performance of models

Table 5: Recommendation System (output)

EMP_AGE>25	EMP_EXP>10	EMP_TRAIN=Yes	EMP_A = Yes	EMP_WH<10	OUTPUT
1	1	1	1	1	1
0	1	1	1	0	1
1	0	1	1	1	1
1	1	0	0	0	0

The best fit model of the XGBoost classifier acts as recommendation system. This recommendation system works based on rule-based classifier for finding the solution.

The primary influencing attributes consider for this system as an input. It predicts the output and finds the recommendation as in Table 5.

6. ORGANIZATION OF THESIS

- **Chapter 1:** *Introduction,* discusses the concepts of fireworks manufacturing process and the risks involved in it. The chapter further discusses the importance of data collection and analytics in the fireworks industry.
- **Chapter 2:** *Literature Review and Data collection.* discusses the works related to fireworks industry risks and hazard identification and safety enhancement. Also discusses the modern machine learning and neural network approaches that can be utilized in analysis of safety standards and predictions of accidents in fireworks industry. to collect data regarding risks and hazards that impacts the safety standards of the fireworks industry starting from the manufacturing to handling of end products. Data collection methods is discussed.
- **Chapter 3:** *Hazard and Risk assessments in fireworks industry,* the common techniques for analysing the risk assessment in industries were applied in this firework industries to identify the risk zone and reduce the risk level by the use of risk reduction priority method are also discussed.
- **Chapter 4:** *Design of Machine Learning analysis of accidents with regard to influencing factors of atmospheric conditions*, the impacts of atmospheric conditions identify from the past accidents, prediction of accidents and increased safety standards are also discussed.
- **Chapter 5:** *Impact of zeolite react with the chemical substance to maintain atmospheric condition*, its analysed maintain the stability of atmospheric condition for reducing accidents are also discussed.
- **Chapter 6:** *Apply the machine learning algorithm for identify the human influencing factors* discussed in this chapter.
- **Chapter 7:** *Results and Discussions,* Results of the proposed works, comparison of the proposed works with existing or benchmark models is are discussed.
- **Chapter 6:** *Conclusion and Future work*, summarizes the contributions of the research and the scope for future research as well.

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